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Experimental Investigation to Optimize Process Parameters in Drilling Operation for Composite Materials

G.Srikanth Reddy, Ranjith Kumar

***Abstract*— This paper discusses the influence of cutting parameters in drilling of carbon fiber reinforced composites. Experiments are conducted to study the effect of point angle, spindle speed and feed rate on Material Removal Rates. Theoretical calculations are done to calculate thrust force and torque. The work piece and tool assembly are modeled in Pro-Engineer. The input parameters considered are;6.5mm and 10.2mm diameter drill bits with 118° and 120° point angles, spindle speeds 1000rpm, 1500rpm & 2000rpm, feed rate 30mm/min. Different combinations of the above parameters are considered to get the maximum value of MRR. Structural analysis is done on the assembly to verify the stresses for different materials like Mild Steel, Aluminum alloy and Carbon fiber reinforced composites.**

***Index Terms*— Cutting Parameters, Modeling, Structural analysis.**

I. INTRODUCTION

In drilling operation, the quality of hole is an important requirement for many applications. Thus, the choice of optimized cutting parameters is very important for controlling the required hole quality. Composite materials play an important role in the field of engineering as well as advance manufacturing in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace and automotive industries.

The objective was to establish a correlation between cutting velocity and feed rate with the delamination in a CFRP laminate. The correlation was obtained by multiple linear regression. Finally, confirmation tests were performed to make a comparison between the results foreseen from the mentioned correlation. The ANOVA is employed to investigate the cutting characteristics of CFRP's using high speed steel (HSS) and Cemented Carbide (K10) drills [1].

High speed machining is now acknowledged to be one of the key manufacturing technologies to ensure high productivity and throughput. Drilling of CFRP, though a challenging task is being performed successfully at low spindle speeds. However high speed drilling in CFRP thin laminates has not been explored much [2].

Grey fuzzy is recently employed by many researchers in optimizing conventional and non-conventional machining processes such as milling, grinding, turning, drilling, EDM etc. In this work, Taguchi's L_{27} orthogonal array of experiments was performed in turning Al-SiC MMC using PCD tool [3].

Experimental investigation of a full factorial design performed on thin CFRP laminates using K20 carbide drill by varying the drilling parameters determine optimum cutting conditions. The hole quality parameters analyzed include hole diameter, circularity, peel-up delamination and push-out delamination. Analysis of variance (ANOVA) was carried out for hole quality parameters and their contribution rates were determined. Genetic Algorithm (GA) methodology was used in the multiple objective optimization (using MATLAB R2010a software) to find the optimum cutting conditions for defect free drilling. Tool life of the K20 carbide drill was predicted at optimized cutting speed and feed.

II. EXPERIMENTAL INVESTIGATION

In figure.1 & figure.2, drilling operations are conducted on the Carbon Fiber piece with 6.5mm and 10.2mm diameter drills with 118^0 and 120^0 point angles with different cutting parameters. The cutting parameters are spindle speed – 1000rpm, 1500rpm and 2500rpm,Feed – 30mm/min.

Fig.1. drilling a hole on carbon fiber material.

Drilling operations are performed on the carbon fiber block by varying spindle speed at constant feed rate as shown in figure**.**1 and the figure.2 shows after completion of work.

Fig.2. Carbon Fiber block with different hole diameters.

Cutter Data	Speed (rpm)	Feed (mm/min)	Time
118^0 – 6.5mm drill	1000, 1500, 2000	30	1min 35 sec
118^0 –10.2mmdrill	1000, 1500, 2000	30	1min 36 sec
120^0 – 6.5mm drill	1000, 1500, 2000	30	1min 43 sec
120^0 – 10.2mmdrill	1000, 1500, 2000	30	1min 45 sec

Table.1

In Table.1, the values of drilling on the carbon fiber with different point angles with different diameter and with varying spindle speed.

Calculations for Material Removal Rate:

$Q = V_f \times \pi \times D_c^2 / 4 \times 60$ mm^3/sec

Feed / revolution $f = f_z \times z$

Where, z = No. of teeth, $f_{z\,=}$ feed/edge

Feed rate $V_f = f \times n$ ($Vf_{\,=}$ penetration rate)

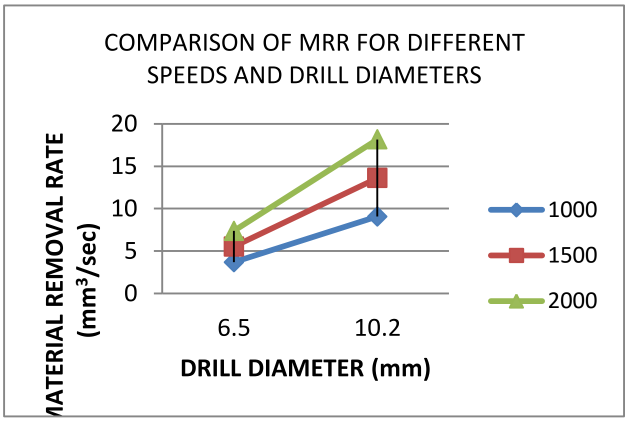

Fig.3. Material Removal Rate graph

Graph is plotted for spindle speed to drill diameter. This shows how the MRR is increasing by increasing the drill diameter and spindle speed as shown in figure.3.

III. 3D MODEL OF DRILL BIT

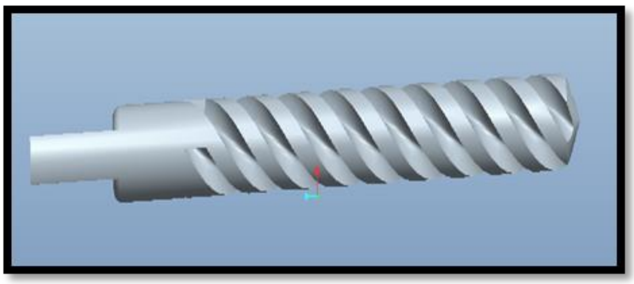

Fig.4. 3D model of drill bit

Theoretical Calculations:

For 6.5 mm diameter

Speed (rpm)=1000rpm, 1500rpm and 2500rpm

Cutter speed

$V_c = \frac{D\pi n}{1000}$ m/min

Torque = $\frac{Pc \times 9500}{n}$ (or) $\frac{Dc2 \times Kc \times f}{8000}$

Dc = dia of drill

n = spindle speed

Pc = power required

Kc = cutting force, d = dia of hole

Cutting Force

F = $\frac{K' \times Kc \times f \times d}{2}$

Material Properties:

The materials considered for work piece are Aluminum, Mild Steel and Carbon Fiber and the values are compared by analysis. The cutter material is HSS.

	Al	Mild steel	Carbon fiber	HSS
Young's Modulus (GPa)	66.59	210	150	235
Density (g/cc)	2.75	7.65	1.76	7.7
Poisson's ratio	0.33	0.3	0.27	0.3

Table.2

IV. STRUCTURAL ANALYSIS

6.5mm Diameter – 118^0 Angle

Aluminium:

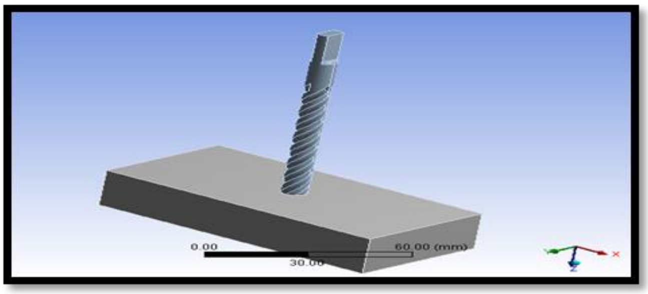

Fig.5.Imported Model

Figure.5 depicts the model imported in to Ansys which is modeled in Creo 2.0.

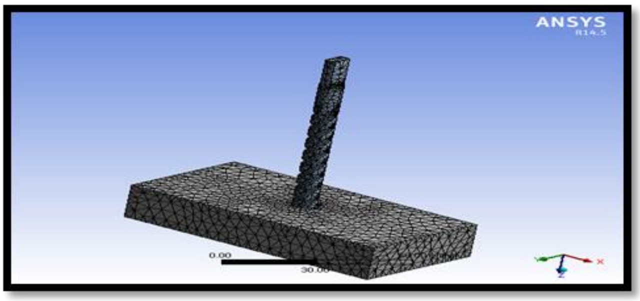

Fig.6.Meshed model

Figure.6 depicts the meshed model; meshing is done using tetrahedron mesh.

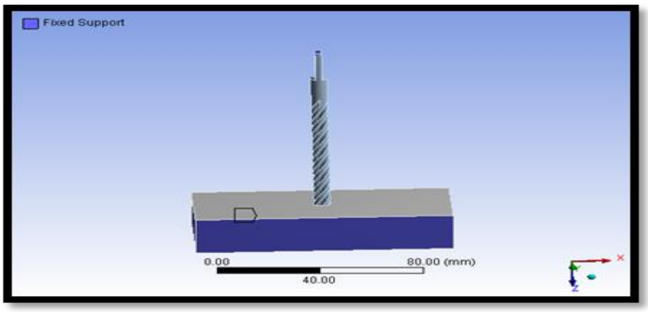

Fig.7. Fixed support

Figure.7 depicts the surfaces on which fixed support is applied (i.e.) they have all DOF.

Force applied is 487.5N.

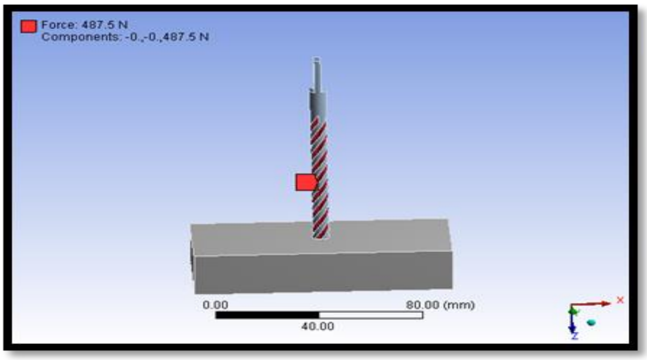

Fig.8. Force applied

Figure.8 depicts the area on which cutting force is applied.

Deformation:

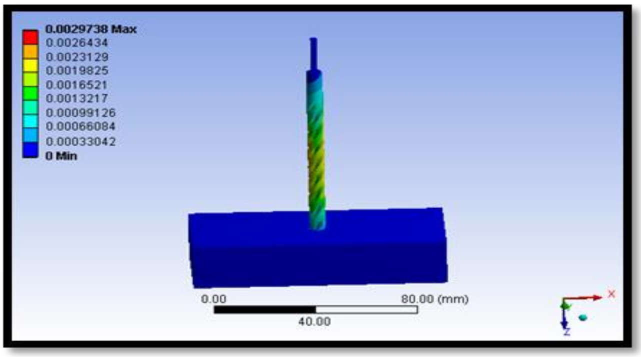

Fig.9 Deformation

Deformation of the tool and work piece after applying the force is shown in figure.9. It shows maximum deformation on tool flutes and minimum on the work piece and top of the tool.

Stress:

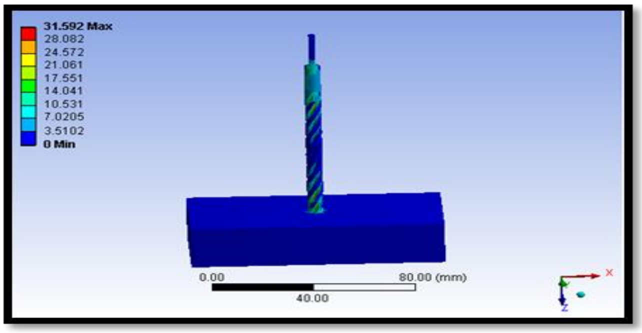

Fig.10. stress on the tool and work piece

Stresses developed on the tool and work piece after force is applied is shown in figure.10. It shows maximum stress on tool and minimum on the work piece and top of the tool.

Strain:

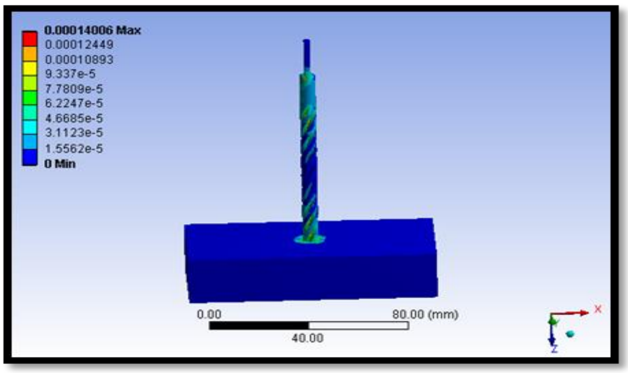

Fig.11. Strain on the tool and work piece

Strain on the tool and work piece after applying the force is shown in figure.11. It shows maximum strain on tool and minimum on the work piece and top of the tool.

V. RESULT

Structural analysis for drill diameter 6.5mm:

Angle		Al	Mild steel	Carbon fibre
118^0	Deformation (mm)	0.00297	0.0095	0.0020
	Stress (MPa)	31.592	101.58	21.312
	Strain	0.00014	0.0004	$9.45e^{-5}$
120^0	Deformation (mm)	0.00294	0.0095	0.001
	Stress (MPa)	30.033	100.29	20.861
	Strain	0.00012	0.0004	$8.93\ e^{-5}$

Table.3

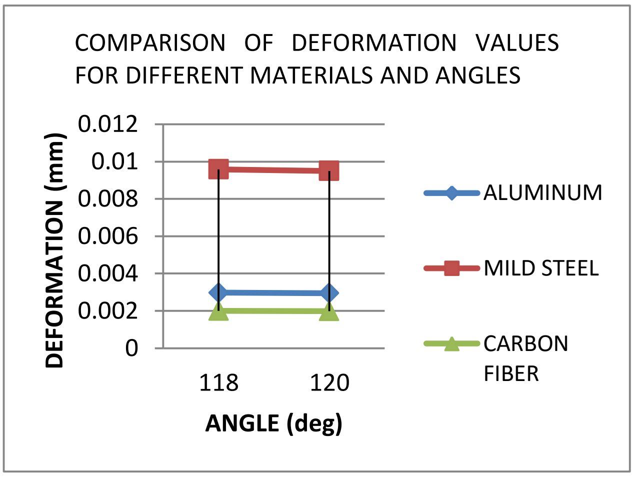

Fig.12. Deformation Vs Angle graph

Graph is plotted for deformation to angles in figure.12. This show the deformation values are almost constant by varying the drill angle and it is less for Carbon Fibre material.

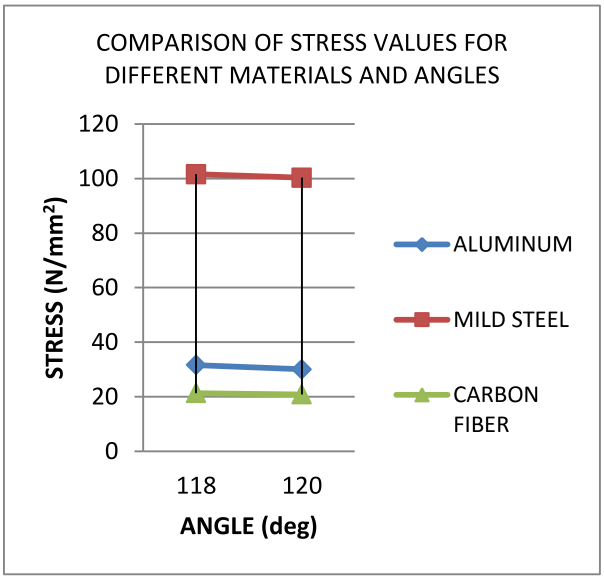

Fig.13.Stress Vs Angle graph

Graph is plotted for deformation to angles in figure.13. The stress values are almost constant by varying the drill angle and it is less for Carbon Fiber material.

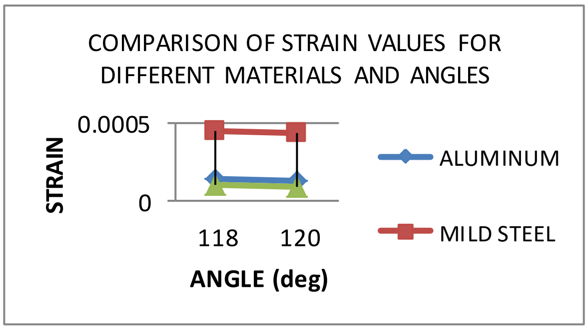

Fig.14.Strain Vs Angle graph

Graph is plotted for deformation to angles in figure.14. The strain values are slightly decreasing by increase of drill angle and it is less for Carbon Fiber material.

Structural analysis for drill diameter 10.2mm is shown in Table.4:

Angle		Al	Mild steel	Carbon fiber
118^0	Deformation(mm)	0.0009	0	0
	Stress (MPa)	10.81	32	6.92
	Strain	5.5 e^{-5}	0.001	3.6 e^{-5}
120^0	Deformation(mm)	0.0009	0.0028	0.0006
	Stress (MPa)	14.574	57.688	11.102
	Strain	9.9 e^{-5}	0.0002	5.1 e^{-5}

Table.4

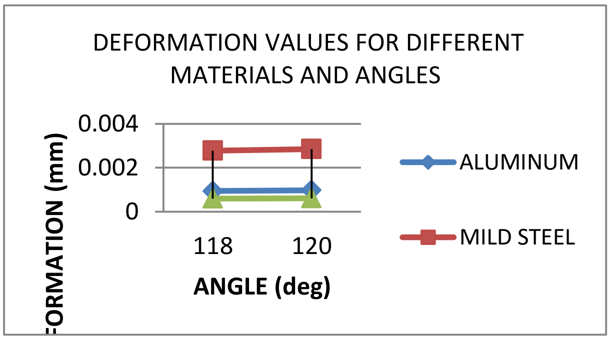

Fig.15.Deformation Vs Angle graph

Graph is plotted for deformation to angles in figure.15. The deformation values are almost constant by varying the drill angle and it is less for Carbon Fiber material.

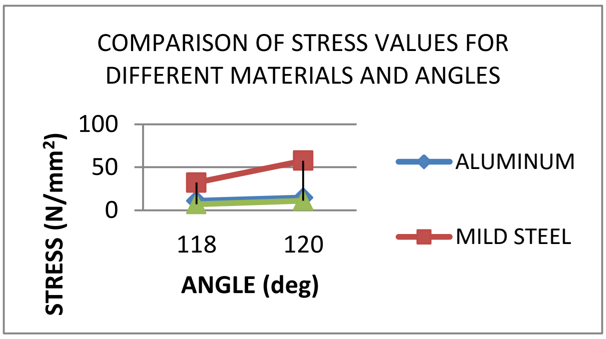

Fig.16.Stress Vs Angle graph

The stress values are increasing by increase of drill angle and it is less for Carbon Fiber material and the graph is plotted for deformation to angles in figure.16.

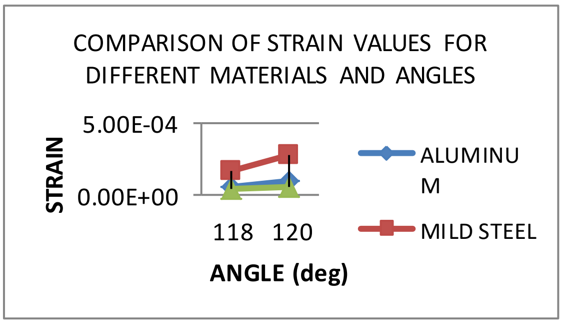

Fig.17.Strain Vs Angle graph

The strain values are increasing by increase of drill angle and it is less for Carbon Fiber material and the graph is plotted for deformation to angles in figure.17.

VI. CONCLUSION

In this thesis, drilling operations are conducted on the carbon fiber with 6.5mm and 10.2mm diameter drills with 118^0 and 120^0 point angles with different cutting parameters. The time taken for drilling is less for 118^0 and 6.5mm diameter drill. The stresses are more for 120^0 angle and 6.5mm diameter drill.

By observing the results, the material removal rate is increasing by increasing the drill diameter and spindle speed.

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REFERENCES

[1] J.P. Davim, Pedro Reis “Study of delamination indrilling carbon fiber reinforced plastics (CFRP) using design experiments”, Composite Structures 59 (2003) pp. 46.51–46.57

[2] Vijayan Krishnaraj, A. Prabukarthi, Arun Ramanathan, N. Elanghovan, M. Senthil Kumar. “Optimization of machining parameters at high speed drilling of carbon fiber reinforced plastic (CFRP)laminates”, Composites: Part B 43 (2010.2) pp.1791–1799

[3] A. Krishnamurthy, S. Rajendra Boopathy, K.Palanikumar, J. Paulo Davim. “Application of grey fuzzy logic for the optimization of drilling parameters for CFRP composites with multiple performance characteristics” , Measurement 45 (2010.2) pp.10.26.56 –10.296

[4] S.R. Karnik , V.N. Gaitonde , J. Campos Rubio, A. Esteves Correia , A.M. Abrao , J. Paulo Davim. “Delamination analysis in high speed drilling of carbon fiber reinforced plastics (CFRP) using artificial neural network model”, Materials and Design 29 (2006.5) pp.1766.5–1776

[5] Islam Shyha , Sein Leung Soo, David Aspinwalla ,Sam Bradley “Effect of laminate configuration and feed rate on cutting performance when drilling holes in carbon fibre reinforced plastic composites” Journal of Materials Processing Technology 210 (2010)pp.1023–1034

[6] S. Madhavan, S. Balasivanadha Prabhu “Experimental investigation and Analysis of Thrust Force in Drilling of Carbon Fibre Reinforced Plastic Composites using Response Surface Methodology”, International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.4, (July-Aug. 2010.2) pp.2719-2723

[7] E. Ugo. Enemuoh, A. Sherif El-Gizawy, A.Chukwujekwu “An approach for development of damage-free drilling of carbon fiber reinforced thermosets”, IJMTM 41 (2001) pp.1795–16.51